Survey of Haptic Technology and Entertainment Applications

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***Abstract*— When someone thinks of gaming entertainment, they think of many gaming outlets such as PlayStation, Xbox, Nintendo, and more. All those different gaming systems accomplish one common task: to entertain the user. A particular system such as Oculus Quest or virtual reality (VR) accomplishes the goal of entertainment, and its applications are used in different fields such as the health field, the real estate market, and even the automobile industry. Virtual reality is a three-dimensional (3D) computer simulation that portrays the real world in a digital realm in which the user can interact within that virtual space. Haptic technology interface provides a sense of touch as feedback. Both virtual reality and haptic technology can enhance users' experience and enrich their source of entertainment. Virtual reality has evolved in the entertainment industry from interacting within a bulky machine to a more portable and personalized experience such as the use of a haptic suit, which provides haptic feedback and further helps the user feel more immersed. Various technologies have been used to improve or promote user inclusiveness and experience, including haptic feedback, which allows the user to feel a reaction--whether it's low haptic feedback (vibration) or high feedback (intense application of force on the user's muscles). The purpose of this paper is to survey recent and innovative applications such as haptic feedback and how it applies to various domains such as virtual reality. Another aspect that will be investigated is the specific framework that provides plausible special effects for the end-user. Result show that haptic technology enhances the virtual reality experience.**

Keywords— Haptics, Haptic media Broadcast, virtual reality, Haptic Feedback

I. INTRODUCTION

As the coronavirus (COVID-19) pandemic ravages the world, with widespread outbreaks and death cases being on the rise, people now more than ever need entertainment and interaction. Luckily, virtual reality combines with haptic feedback fulfills that need. Virtual reality uses special electronic equipment such as a headset goggles, gloves, or even a suit, allowing users to be interactive in a virtual environment without the risk of passing or catching the virus [1]. Haptic broadcasting is the process of sending the haptic signal to a device in a location. Haptic technology, also known as kinesthetic communication, refers to any technology that can create an experience of touch by generating forces, vibrations, or motions for the user [2]. This technology, combined with virtual reality, can increase users' experience based on the user's activity. This research paper will review applications in the Gaming and Entertainment Industry. Additionally, it will discuss the framework of haptic broadcasting feedback and how it relates to these industries. This research will benefit students, engineers working in VR game design, and instructors who want to stay abreast of research currently being done in virtual reality.

II. BACKGROUND

A. History

According to Emspak, in the 1930's virtual reality was first introduced. It was not referred to as a computer that made users' feel immersive; rather, it was referred to as a theater. In the 1960s, a cinematographer by the name of Morton Hellig, invented a machine called the "Sensorama." The machine used wraparound screens viewed with a binocular-like device to get a 3-D effect [3]. The Sensorama machine had several components, stereoscopic images, a motion chair, audio, temperature changes, and odors that were used to stimulate the senses of an individual. He used the machine at a movie theater. It would trigger different scenes and either move the seat, blow air from the vents, or activate the stereo sounds to simulate an experience such as riding a motorcycle [4].

Likewise, in the gaming industry, the Virtuality Group created VR arcade games and made them available to the public. Features such as multiplayer were accessible via networking the machines together. Some of the famous games such as Pac-Man had VR versions. The players would interact with the machine by wearing a set of VR goggles and interact with the game. It was impressive at its time because the latest latency time was less than 50 microseconds [5].

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A reader might be interested to know what precisely haptic feedback provides. Haptic feedback offers device sensations. For example, consider when a cell phone vibration or the sensation a user feels when interacting within the virtual world. Thus, what effect if any does haptic feedback have on user experience? In [6], the author discusses that the type of feedback makes an excessive difference in the user's experience. He tested 26 subjects and made them go through three different kind of experiences--no haptic feedback, low fidelity haptic feedback, and high-fidelity haptic feedback. One example is a baseball virtual game that simulated the impact between a virtual baseball bat and ball. Out of those three experiences, the author noticed more users were highly pleased with the high-fidelity haptic feedback in which they stated that it increased the quality and experiences and enhanced realism.

Fig1. Virtual Reality Arcade Machine

B. Augmented and Virtual Reality Haptics

According to Tideman et al, some of the current trends are using VR in applications such as gaming. A particular game called Pistol Whip puts the users in a pulsating environment and rewards them for firing bullets in time to a rhythm. The game's objective is to shoot the enemy at the rhythm of the music. Virtual reality is used in various applications such as a concert in the entertainment industry. This feature allows individuals who do not have access to concert venues to enjoy their favorite artist or band *[7]*.

Additionally, in [8] , the authors discuss the recent development or techniques between human and computer interaction. Factors such as hardware and software play a critical factor to smoothly ensure application features that use touch, feel, and object manipulation work correctly. However, with all technology, there are common issues that arise when using that technology such as how to program the sensors and how to render the haptic feedback.

Similarly to [8], in [9] the authors analyze the technology that enables artificial touch sensations and that of a human touch. That technology provides users with many features such that it helps them to complete tasks and add realism to their virtual interaction. Furthermore, the authors discuss the different forms the haptic device can take and some challenges and limitations of each feedback modality.

Moreover, in [10], the authors analyze augmented reality where users can only watch the object without interacting with it. The authors' proposed using an input system called PHANTOM that is used to generate a sort of haptic interface--a device that measures a user's fingertip position and exerts a force on the fingertip. Moreover, PHANTOM can be used to generate the stimuli perceived by users' senses such as touch, sight, and smell. The users can perform different interaction activities such as moving, lifting a virtual object, and interacting between a real and virtual object.

The authors in [11] further explore the integration of haptics in augmented reality to not only help users when playing games such as Ping-Pong but also apply those applications or concepts to help users practice surgery in a virtual surgical environment. When dealing with such delicate matters, the virtual machine tools had to be calibrated correctly and precisely so that they would be reliable. Also, latency had to be low. The authors created a distrusted framework that accomplished those tasks previously mentioned.

C. Haptics in Entertainment

User experience is key when developing or adding haptics in virtual worlds. Di Dang, a user experience (UX) designer for virtual reality, augmented reality, and mixed reality, discussed how critical it is for the implementation of haptics in virtual reality. She states that haptic is full of mystery and possibility and is the last realm of discovery in the virtual world [12].

Some gaming concepts are used in virtual reality to help the elderly. In [13] , the authors discussed how some concepts found in gaming console such as *Nintendo Wii*, computers games, dance video games with the floor pad were used to help the elderly be more physical and active. Additionally, those concepts or tools were also used for rehabilitation.

Moreover, haptic concepts are being used in many applications. One of which is found in a patent [14]. The inventor, Robert W. Heubel, created a system that generates haptic effects on mobile devices during a group event. The system works similarly to the alert people receive on their mobile phones such as Amber or a weather alert. The system determines the type of haptic that needs to be broadcasted to a specific group.

Additionally, haptics feedback features are being added in virtual reality. In [15] , the authors analyze how to add haptic feedback to virtual objects such as a wall. For example, if the user creates a virtual space or virtual wall to prevent either running into a wall or hitting a real live object, and that wall has haptic feedback, whenever the user tries to push pass it, it will send an electric signal to the user's shoulder, arm, wrist, to let

the user know to pull back. Other objects in the virtual reality space also had haptic feedback such as boxes, sliders, all of which help the user to feel more engaged with their surroundings.

In [16], the authors proposed a Haptic broadcasting system which allows the users to play a game of badminton by transmitting content such as audiovisual within the broadcasting infrastructures. This feature allowed for real-time play experience in which television audiences were able to watch.

With haptic feedback being in many applications such as console, PC game systems and more, the authors Joshi and Salisbury, analyze a competitive network game called “Haptic Battle Pong” which uses the three-degree-of-freedom force feedback and six-degree-of-freedom input to fully experience the high-fidelity haptic feedback in the game. Moreover, the authors discuss several methods used to improve traditional video games using haptic feedback features [17] .

D. Haptic Broadcast Framework

Since haptic feedback increases realism, which in turn makes a user have a positive experience, it is worthwhile to discuss the framework that makes this work possible. In [18], the authors discuss the implementation of a prototype system and demonstrating two possible contents, MPEG-4 and IEC/ISO, used to achieve haptic streaming media that can be used for in-home shopping and live events. A downside to those contents, are possible issues that might arise such as content processing and viewing and interacting with the media.

Also, in [19], the authors were tasked with enhancing the user's experience while watching videos to increase realism by including haptic effects in the user's environment. The authors achieve that task by extending the development of a framework where users can feel motion when watching content such as a movie that has movement.

Moreover, in [20], the authors analyze how to compute haptic structure signals from the depth of an environment and 3D scenes. Additionally, they use similar methods to capture and calculate the 2D video haptic structures and motion. All of which helps the user to be more immersed in their environment and increase their experience.

Furthermore, in [21], the authors discuss the possibility of collecting and capturing sensation data through Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). Unfortunately, neither method will help the quality of data transmission, which as a result, might lead to jitter, delay, and loss of data when users are interacting in the virtual world.

Different applications will require different devices, which will have different haptic feedback sensations. In [22], the authors analyze the hardware technology, eccentric rotating mass, and linear resonant actuator needed to obtain the different haptic feedback effects in the remote-control devices. Based on the result of the study, most users prefer an interface with haptic feedback.

While in [23], the authors propose an architecture that captures high resolution haptic feedback while users play games. This architecture was composed of different parts: haptic engine, haptic API/codec, and haptic display. All of which help the users to feel high refined tactile sensation on their body while playing their game.

With the need to share data being on the rise, people want a network topology that is both reliable and fast. Thus, scientists developed 5G since it provides more bandwidth and users will be able to download content much faster. In [24], the authors analyze the necessary infrastructure that is needed for haptic feedback to integrated within a 5G network.

Many devices that people use provide some sort of feedback whether it be cellphones, tablets, or smartwatches that make haptic alerts very challenging. In [25], the authors created a framework that allows devices to automatically adjust their levels of haptic response based on the density of the content and utilize the network to eliminate redundant alerts. Furthermore, the author proposed an intercommunicating network that would allow a small lag time between device alerts.

In [26], the authors proposed a framework called “Stereohaptics” which is a tool to perform several actions such as to create, record, and modify. This tool is useful for the music industry, artist can make use of those tools to design haptics experiences that everyday users can use on their devices whether that be mobile device, computers, toys or game controllers.

Moreover, in [27], the authors proposed a multiple sensorial media framework that would deliver video and other sensorial information’s to users. This framework surpasses other framework in terms of user’s quality experience since it involves multiple sensory at play, which in turns increases user’s realism and immersiveness.

III. CHALLENGES

There are many challenges in the field of virtual reality that experts encounter. Among them are designing a haptic interface, developing better tracking systems, and implementing better haptic function and interaction. When creating a haptic interface, the developer has several factors to consider, such as the type of hardware used to achieve the kind of feedback needed to accomplish its goal. Moreover, perception might differ from one person to another based on that individual's experience. The sensation the users feel on

their skin differs from person to person. Each person's skin has a specific sensitivity [28].

A. *Tracking System*

Experts have to make sure the sensation the user feels is appropriate to what the user is doing in the VR environment and does not increase latency or lag. That application is challenging to achieve because haptics requires at least 500 to 1,000 Hz to refresh, making it even harder to track users accurately and gather that information from the haptic device to prevent a user from running into a real-world object [29].

B. *Haptic Function and Interaction*

Lastly, the expert in the field has a problem creating the feeling of "feel." For example, when the user is in free space, the space should feel open and empty with no restriction. When they are in an enclosed space, the user should feel a hard texture object or wall. Additionally, experts have difficulties developing and perfecting the different type of tactile feedback: mechanical vibration, surface shape changing, and friction *[30].*

IV. REFERENCES ANALYSIS

In a *Play Station 4 (PS4)* console, the controller sometimes vibrates or provides haptic feedback if the character runs into a wall or receives damage. Haptic virtual reality uses the same concepts to provide similar sensations. According to M. Y. Sung et al., the authors argue not only is it possible to obtain that sensation of the user holding a ball, but they can use transmission control protocol and user datagram protocol to achieve that goal [21]. The only disadvantage of using either TCP or UDP is that neither could enhance data transmission, which results in delay, lag, and loss of data. Nevertheless, they take advantage of recent hardware and software--two pen-based PHANToM--to integrate force feedback into the network. The difference between haptic feedback and force feedback is that haptic feedback is provided through the sense of touch and is less intense. For example, cell phone vibration is haptic feedback. Force feedback incorporates haptic feedback and generates enough force that users can feel it through their muscles [21].

In [6] , the author further analyzes if haptic feedback improves the user's experience. He presented his 26 subjects with three feedback types—no haptic feedback, low haptic feedback and high haptic feedback. The result corresponds with Di Dang's, statement that haptic feedback helps the user feel more immerse in their virtual surrounding [12]. After obtaining the results, most users were highly displeased with "no haptic" as presumed, while others were moderately pleased with low-fidelity haptic. The others were highly pleased with high-fidelity haptic feedback in which they say it increases the quality experiences and enhanced the realism of hitting the virtual baseball bat [6]. Comparing the results of Ryge et al., it can be concluded that having a high-fidelity or force feedback will help further increase realism and user experience.

Moreover, in the Haptics domain in Augmented Reality and Virtual Reality, the authors in [8] discuss the development in human and computer interaction, all of which is possible through hardware and software. While in [9], [10], [11], the authors further improve the concepts of human-computer interaction by enhancing the users' experience and implementing haptic feedback in their virtual surroundings.

In the entertainment field, such as gaming, the authors in [12], [16], [17] focused more on making the gaming experience more interactive and real for users. While in [13] , the author extends the haptic feedback application in gaming into helping the elderly.

Lastly, in Haptic Broadcast Framework, systems are put in place to capture and stream haptic concepts [18], [20], [21], [23], [27] ,part of an effort to deliver an enjoyable haptic experience to the users while they are either streaming a movie [19], playing video games [23], or creating music [26]. Finally, with 5G being the framework of future communication, development and research are underway to incorporate haptic methods to work with 5G and deliver a memorable experience to the end-users [24], [25].

V. DISCUSSION

1. Haptic Feedback Embedded in Virtual Reality

Improving the sensation of having game controllers shake or vibrate whenever a player gets hit or injured is to embed haptic feedback in virtual reality. Haptic feedback helps users feel more immersed in the game. In [8], an experiment was conducted to analyze the interaction between users and object stiffness using visual and auditory cues. The result shows how critical it is to have visual and auditory information synchronized; otherwise, it might affect the user's experience. Moreover, it is essential to keep track of the user's position and movement beside their visual and auditory cues. In [10] , the authors used the *Phantom software*, which enables the users to interact with their senses and develop a coordinate technique to find the user's location in the game. The downside of that coordination technique is that it only helps with measurement and camera calibration and not visual augmentation.

2. Haptic Feedback in Entertainment Industry

Haptic technology is successful in the entertainment industry, especially in gaming. In [13] , the authors test the elderly and interactive games such as Nintendo Wii, where one of the main goals is rehabilitation for the elderly population. The game had to have the following attributes: interactivity, entertainment, rules, an opponent, an objective such as collect points or coins, and most importantly, the possibility of winning or losing. After performing the test, there was little to no evidence of improvement in physical functions among the elderly. In [15],

the authors conducted a study in which they rendered haptics objects via electrical muscle stimulation (EMS). Participants wear a head-mounted display and interact with objects in virtual reality. Each item generates a different (EMS). At the end of the study, the authors were successful in achieving the results in their experiment. Users were able to enjoy the interaction and feel the difference of EMS generated from pushing a virtual wall to picking up a virtual box.

3. Specific Framework for Special Effect

Some of the special effects in haptic feedback use a different system to deliver the content to the end-users. In [18], the authors proposed a haptic broadcast system that allows users to interact with a video using MPEG-4 systems standards. In a fictional shopping scene, the host instructs the viewer to interact with the product using a haptic display via a kinesthetic device such as a hap-thimble. To achieve such a task, the authors had to consider the bandwidth and the best way to deliver that content without losing quality. In [27], the authors analyzed that problem by coming up with a method that selects the best or optimal combination for video segments and sensory data for a given bandwidth. Thus, they developed a system called Adaptive MulSemedia Delivery Solution (ADAMS) to prevent end-users from suffering from poor quality experience in a congested network. To test the system using ADAMS, the authors performed a test with users and evaluated the quality of their experience. The result shows that the ADAMS system outperforms the existing multimedia delivery solution in quality and user experience when streaming mulsemedia content.

Throughout the years, several patents have been filed for haptic technology. In [31] , the authors proposed customizing haptic feedback in live events via sensors on entities such as football players. Also, these sensors were used to deliver the data on a haptic device. Moreover, haptic technology has been embedded in several applications in numerous fields such as education, health, and sports.

A. Educational Techniques

Haptic technology is used in education to encourage students to learn and become more interactive with the information. Besides learning by listening or observing, users can now feel the material within the haptic devices [32]. For example, they would an interactive glove. This new feature makes learning more fun and interactive, especially for children who learn more effectively by these interactions. They can manipulate objects in the virtual reality environment. The students interact with a Visual-Haptic system to see the virtual object in a virtual environment through the Graphical User Interface. They use haptic technology to learn different skills such as how to write legibly and neatly. For example, when elementary students learn how to handwrite the alphabet, they first start tracing each letter in a notebook. The haptic technology device uses the same concept, except that the students have a pen device to trace the letters virtually. If the students deviate from the standard trace too much, the haptic device will apply the proper force to guide the students' hands back to the appropriate tracing area.

B. Vital Health Statistics

In the medical field, haptic technology has been used to help patients monitor their health. The sensor-fusion wearable haptic technology combines several features or devices to monitor a patient’s heart rate, blood sugar level, oxygen level, and blood pressure. The sensor-fusion device includes a temperature sensor, a controller board, an accelerometer, and a light-emitting diode[33] . It monitors an individual’s health and sends the data collected to the cloud. Furthermore, the sensor fusion device has color-changing LED lights that let the user know their health state. Users that face an emergency can push a button on the device to get medical help.

C. Sporting Applications

Lastly, in the sports field, haptic technology has been used to help players train better without a coach's physical presence. However, the coach previously programs the device to correspond to the proper exercise. Haptic technology such as insole and haptic armbands are used for the athlete's training. "Smart insoles" have several sensors that fit inside tennis shoes, which collect the player's plantar pressure data during indoor and outdoor activity [34]. These technology systems enhance players' training performance. Additionally, coaches can use an application with the insole and haptic armbands to monitor players' progress and customize their workout. The haptic armbands start with vibration to the user's arm to indicate the start of the exercise. After the allocating time, which the coach sets, the application tells the users to perform the next activity when the former expires. The user is informed whether they need to perform another exercise or rest. Once all exercises are completed, it sends a vibration signal to both armbands letting the user know the training is completed.

VI. CONCLUSION

In this survey paper, the effect of haptics on virtual reality was observed. Components such as the feasibility of collecting or capturing sensation data that allow users to feel objects such as a basketball were explored. As technology continues to improve the way humans communicate, so will the application of haptics. Haptic components are already displayed in vast applications that people use in their daily lives, cell phones, and gaming consoles. It continues to evolve and make a significant impact in different fields besides the gaming entertainment industry. For example, in the health industry, health experts use simulation machines with haptic components to practice surgical procedures. The type of feedback depends on the user's task, which makes a big difference in their experience. Di Dang, a user experience (UX) designer for virtual reality, discusses how critical it is to implement virtual reality haptics. The ability to touch plays an essential role in helping the user feel more immersed in the virtual world. The hardware technology, eccentric rotating mass, and linear resonant actuator can produce different Haptic feedback effects in the remote-control devices. Research has been done to help the elderly be more

active by using concepts found in other gaming consoles found in virtual reality.

In this current time, where most people are working at home due to the pandemic, more industry wants to use virtual reality to help users feel more inclusive. For example, the real estate industry and the automobile industry users will have the opportunity to visit and interact with either the house or car virtually before purchasing it. In the future, haptic feedback will continue to be enhanced and improved in virtual reality. Users will feel an object's texture or feel the virtual world's interaction either when they hit an object such as a wall or received damage in a boxing match game. Haptic feedback is the future. As haptic feedback development increases, further research in the policy or legal field will need to be done. Legal problems, such as crime or murder, arise. For example, if users commit a crime in the real world, thinking they were in the virtual world, would they suffer the real world's consequence? These issues could represent possible legal and moral concerns.

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